Burroughs

RESEARCH

INTERESTING FOREIGN ELECTRON TUBE TECHNIQUES

By

F.R. Michael and T.H. Briggs

AND

THREE DIMENSIONAL TUBE DATA PRESENTATION

By

F.R. Michael

Research Center
Burroughs Corporation
Philadelphia

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This paper was presented at the National Conference on Tube Techniques, October 13, 1953, in New York City by T.H. Briggs.

TITLES AND BRIEF DESCRIPTION OF SLIDES

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b. Swaged mechanically.

c. Black ceramic paste.

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TITLE: Interesting Foreign Electron Tube Techniques

by F. R. Michael and T. H. Briggs, Research Laboratories, Burroughs Corporation, Philadelphia.

INTRODUCTION

The data to be presented in this talk have been obtained from studies and analyses of foreign electron tubes produced during the past eight years. The products of several countries and plants are involved as sources of this material. These represent tubes which are not normally available for comparison by United States tube engineers. The work has been supported by contracts from the United States Government. Its purpose has been to improve quality and reliability of tubes for military use.

A great deal of information has been accumulated which, it is felt, should be made available to the American tube industry for their own study and evaluation. We believe and sincerely hope that some of these findings will result in their incorporation into the procedures of our own industry.

Some years ago, when working in a tube plant, several of us had an opportunity to visit the plants of our neighboring colleagues and vendors. Upon our return, the plant manager asked what we had seen. Naturally we tended to point up the spots where our own plant was better than that of our competitors. We did not get very far with this for we were cut off short with the remark, "I don't want to hear where they are worse than we are. I want to know where they are better so that we may improve". That single remark had a tremendous influence upon all who heard it, and our subsequent trips consequently were of greater value to our parent organization. I would like to use this philosophy in today's talk. No one will dispute me when I say that our own tube industry is the largest and best in the world; but let us see what we can learn to our own advantage from foreign tube practices.

BACKGROUND

The foreign tubes have been compared with American tubes of the closest possible types. The analytical work has consisted of electrical testing, x-ray photographing, studies by use of plastic cross section, mechanical examinations and measurements as well as chemical analysis of materials. Taken individually, the data are of little significance. Taken collectively over a period of time and of space, the results can be extremely valuable and significant.

It is our intent to present only those features in which we have confidence that the supporting data are sufficiently strong to provide a high degree of creditability. We hope our data will be challenging, and will stimulate further study. We do not pretend to provide answers in detail.

First, it is necessary to consider as a background some of the conditions facing the foreign electron tube plants. In general the largest of their tube plants produces fewer tubes than many of the small or medium size domestic plants. While the number of tube types may not be as great as will be found in our own warehouses, the variety of tube families is greater.

Second, the advantages of ample financial budgets to provide automatic equipment are taken for granted in this country. Production of electron tubes requires a variety of highly specialized materials with exceptional control of quality and uniformity. Our large volume usage permits the economic production of much of this material. In European countries where the quantities of materials required are smaller, the economic incentive to the vendor companies is lacking. Further, there are the difficulties of language and national boundaries to be overcome.

Those of you who make tubes can readily imagine the added difficulties which you would daily face should these problems be added to your own.

Mr. Michael and I have spent many years in making radio tubes. We are familiar with the difficulties. We have experienced the problems of attempting

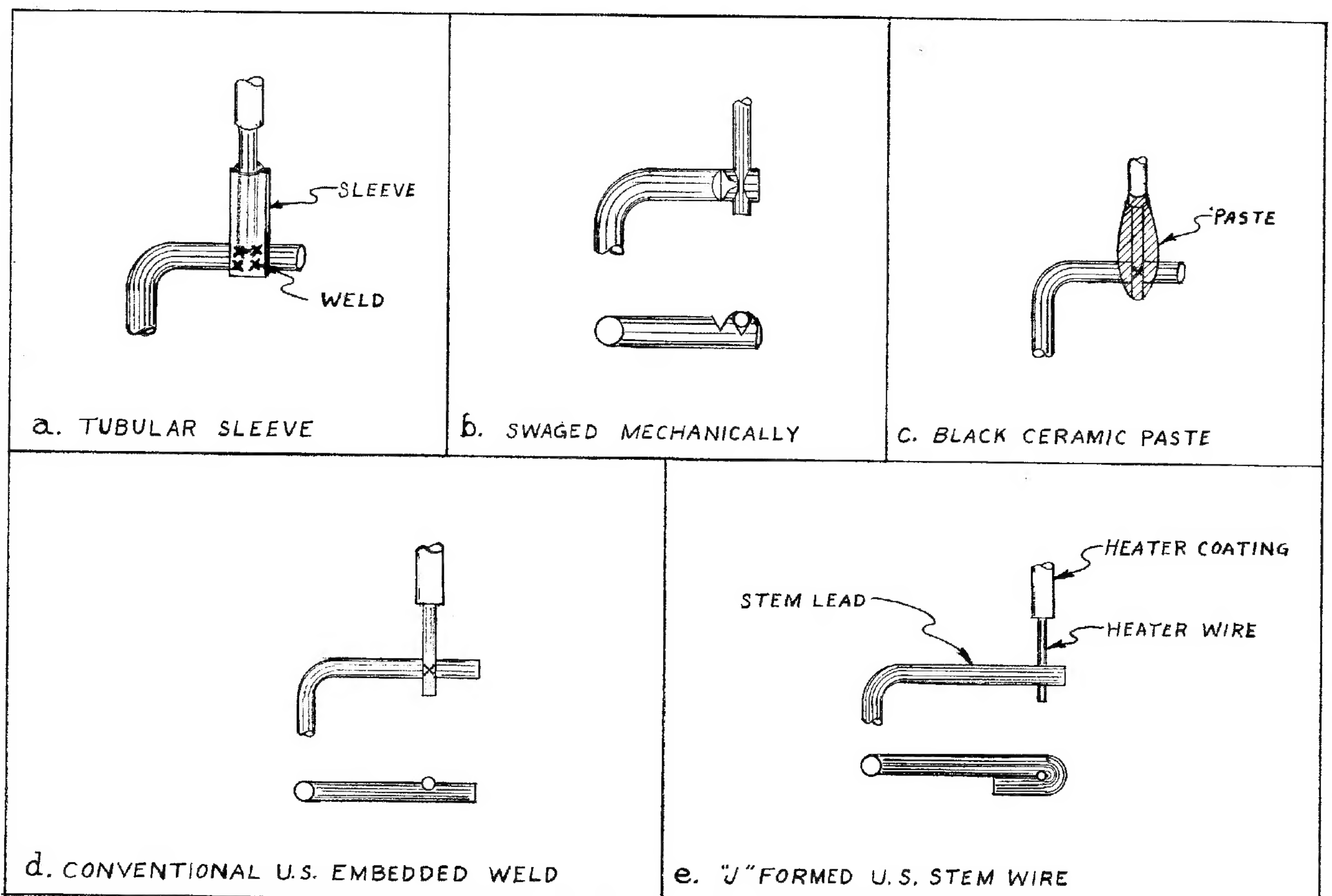
to adopt for procudtion in our own plant the process material or design which has worked satisfactorily in a neighboring plant. So we can acknowledge at the start that many of the points of interest which we will discuss in the foreign tubes can be transposed for domestic use only with difficulty or with major adaptation to our localized practices.

Two major requirements are placed upon electron tubes, mechanical quality and electrical reliability. The mechanical quality, the resistance to shock and vibration, is a function of tube design and the ease with which operators can assemble the parts. The electrical reliabilities which are desired by customers are essentially those of uniformity of initial characteristics and long trouble-free electrical life. Basically life is dependent upon a low rate of barium evaporation, a low gas content and a slow rate of interface impedance build-up on the cathode. In both cases the severity of the tube application conditions are of great importance, not excluding, of course, the environments surrounding the tubes. It is quite probable that the applications demanded of tubes in the United States, particularly those of military equipments and large screen television receivers, are somewhat more severe than the average requirements placed on tubes abroad.

With these conditions in our minds, we have selected several features from the foreign tubes which we believe are of interest to the American tube engineers, and are worthy of further investigation and adoption to use in our own designs.

HEATERS

Slide No. 1 shows methods used overseas for insuring tight welds between the heater wire and stem leads. The first is the well-known tubular connector which is expensive and has been used to some extent on premium grade tubes in this country. The second method is shown by the drawing of a recent and more simple mechanical method for swaging the foreign tungsten heater wire in the



I. HEATER WIRE ATTACHMENT METHODS

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nickel stem leads. This is the one that should appeal in particular to higher production tube types. Apparently a special tool or plier is employed.

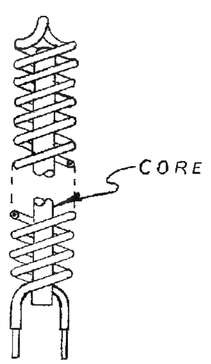
One of the reasons for heater failure is the so-called "lighthouse" effect, wherein the relatively thinnly coated or bare heater wire over-heats when voltage is first applied. One company has painted a black iron oxide paste upon the heater-to-stem wire junction. This not only provides increased mass, but improves the thermal-radiation to avoid local over heating and consequent burn-out of the resistance wire.

The other two drawings are the conventional US embedded weld and the J-bending of the stem wires which is now being used in certain reliable tubes.

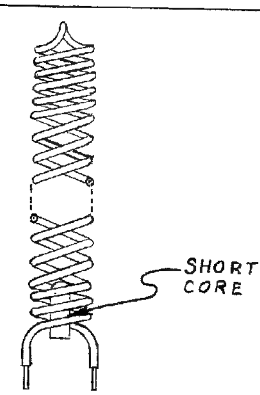
Slide No. 2 illustrates various forms of heater construction. The folded wire and the reverse coil are normally used in this country. The V-shaped single coil is being used more and more extensively in certain tube plants abroad. It is believed that one of the reasons is that these coils can be wound with less complex machines and with less severe requirements placed upon the quality of the tungsten and tungsten alloy heater wire. It is also possible to design a variable pitch for this coil which will provide greater temperature uniformity along the length of the cathode sleeve. Variable pitch heaters are used in a wide variety of tubes from close spaced rectifiers through the RF and power output pentodes. We have found that European engineers do not adopt techniques unless they are well justified both scientifically and economically. There is ample evidence that our own tubes would be improved through greater uniformity of cathode temperature.

MOUNT STRUCTURE

Slide No. 3 shows a photograph of a domestic 6SK7GT tube and its foreign equivalent. Note particularly the shorter base shell and the shorter overall height for the foreign tube. These two tubes have the same type designation and electrical ratings. They are completely interchangeable.

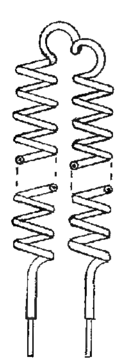


a. REVERSE COIL - CERAMIC CORE - FIXED PITCH

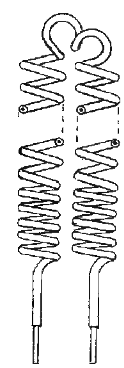


b. REVERSE COIL - SHORT CERAMIC CORE - VARIABLE PITCH

c FOLDED "M" STRAIGHT COATED WIRE



d. FOLDED "V" - STRAIGHT COATED COIL - FIXED PITCH



e. FOLDED "V" - STRAIGHT COATED COIL VARIABLE PITCH

II HEATER DESIGNS

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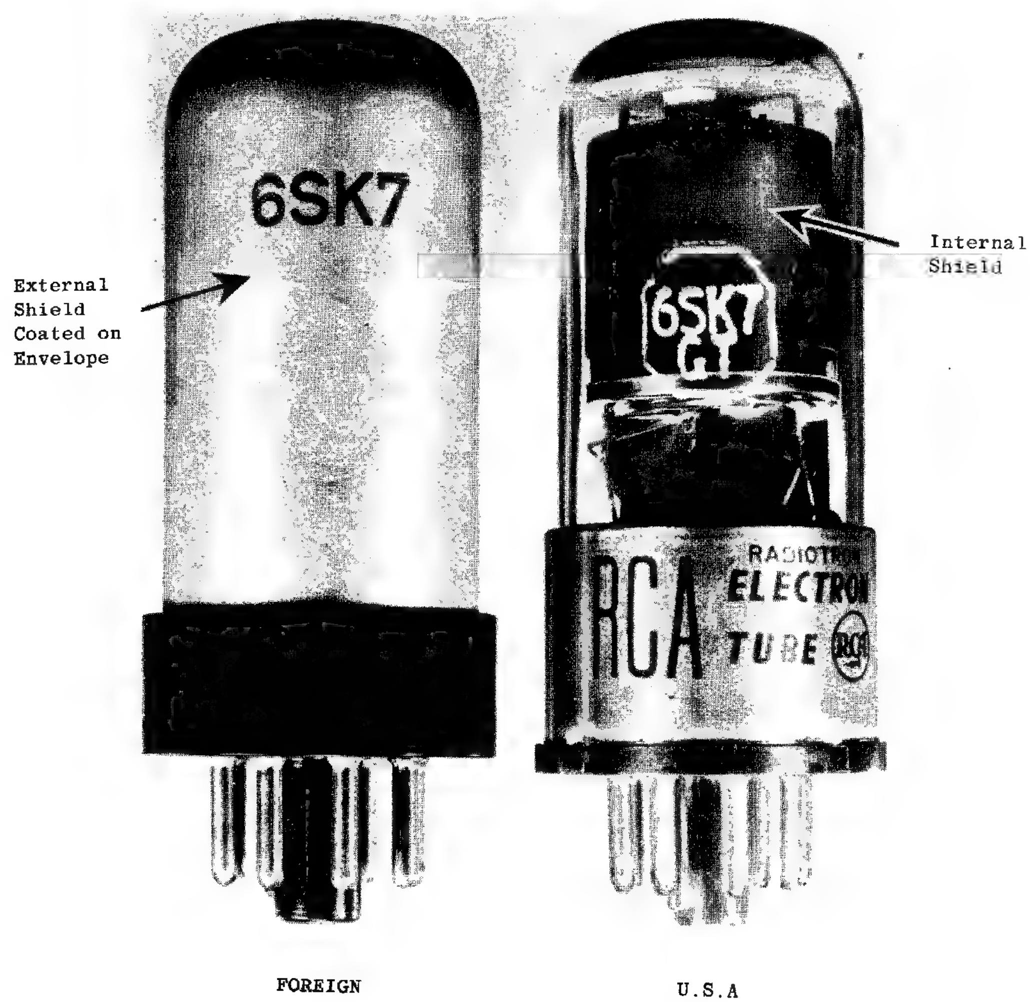


III 6SK7 - FOREIGN AND U.S.A. TUBES

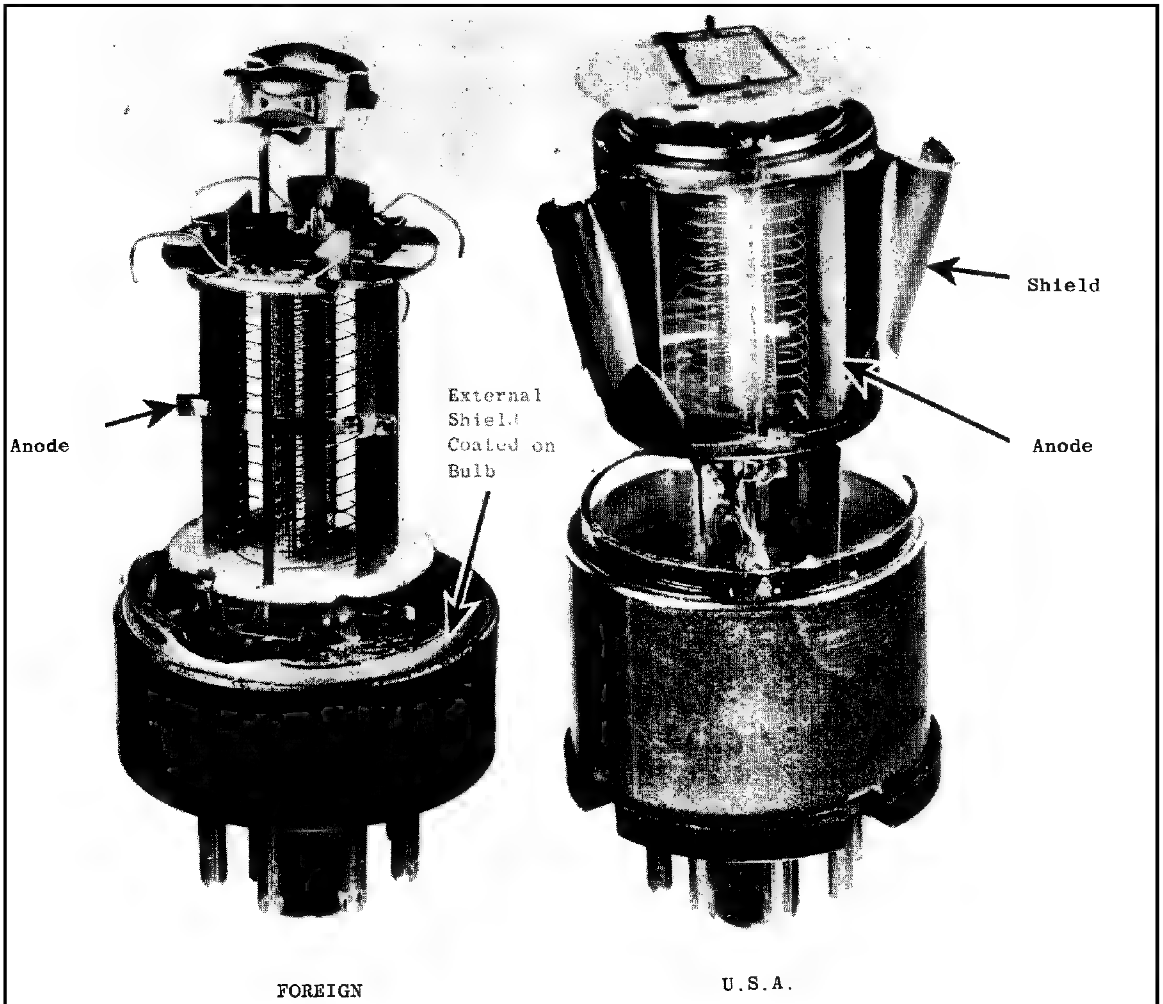
Slide No. 4 shows the same tubes with the bulb removed. Slide No. 5 shows them in x-ray views. Note that the foreign mount is supported by thin dumet lead wires which are annealed and quite weak in comparison with the one millimeter diameter nickel wires used in this country for mount support. The borate coating apparently is removed by sand blasting prior to welding. The shorter mount height is possible by elimination of the pinch type of stem press. Where the getter is at the top of the mount, a larger bulb volume is permitted for getter flashing and there is freedom from reflected getter material upon the insulating mica spacers.

Slide No. 6 shows somewhat more clearly the floating type of mount structure by an idealized drawing. An excellent permanent spring for centering the mount in the bulb and cushioning it against shock and vibration is provided by the "ox-bow" tungsten wire of twelve thousandths of an inch diameter. This frequently permits the mica spacer to be smaller in area and thus conserves the strategic mica material which is extremely scarce in Europe. Tests are in progress to determine whether or not this floating structure with the small diameter annealed lead wires yields a better shock resistance than the standard American receiving tubes.

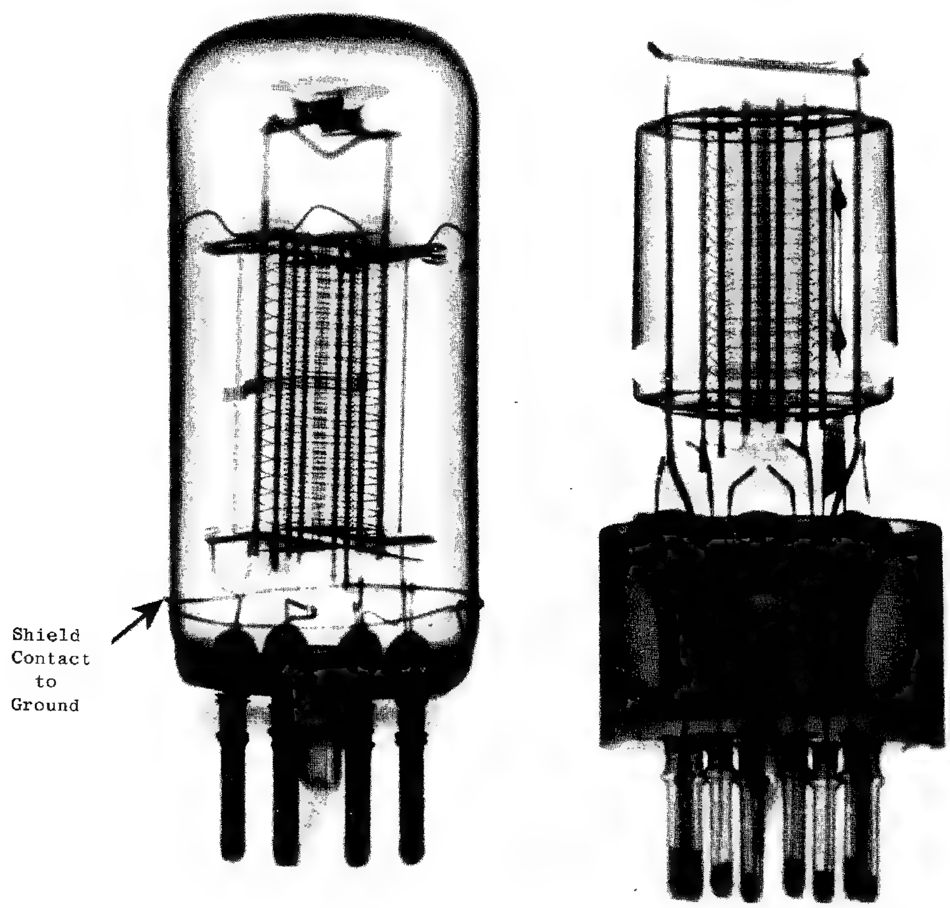
A method of crimping the spring wires to the mount structure has been well standardized for a wide variety of tube types. There is a definite advantage in comparison with the pointed mica contacts with the bulb in that during continued vibration there is no disintergration of the mica into powder which can result in gases which poison the cathode emission.

CERAMIC SPACERS

Slide No. 7 illustrates dramatically the use of ceramic spacers to replace mica in receiving tubes. So far, this has been seen in rectifiers, triodes and tetrode types. Obviously, it will be more difficult to adapt to pentodes and to penta-grid converters. Development work on the use of ceramics in place of

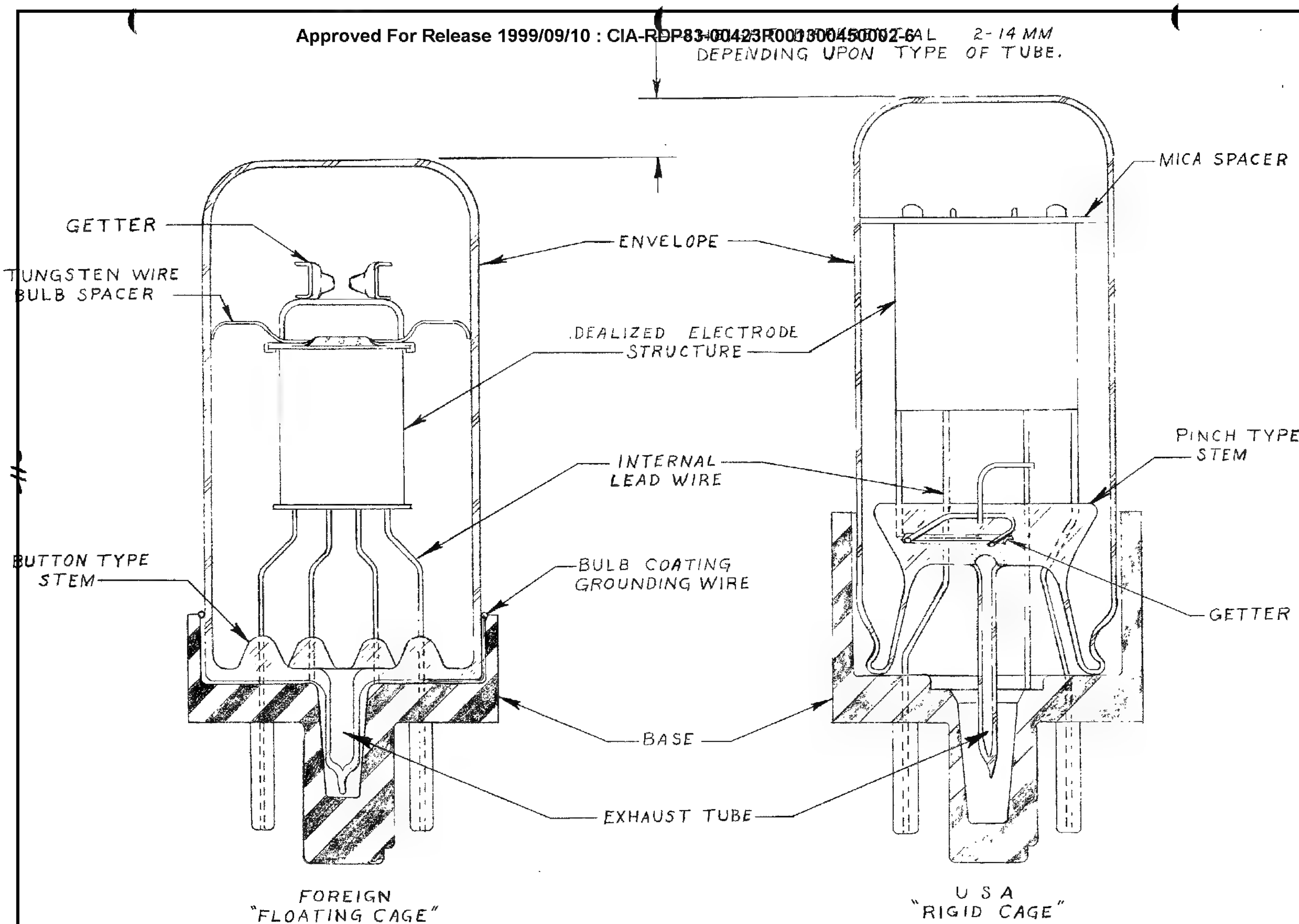


IV 6SK7 - FOREIGN AND U.S.A. TUBE MOUNTS

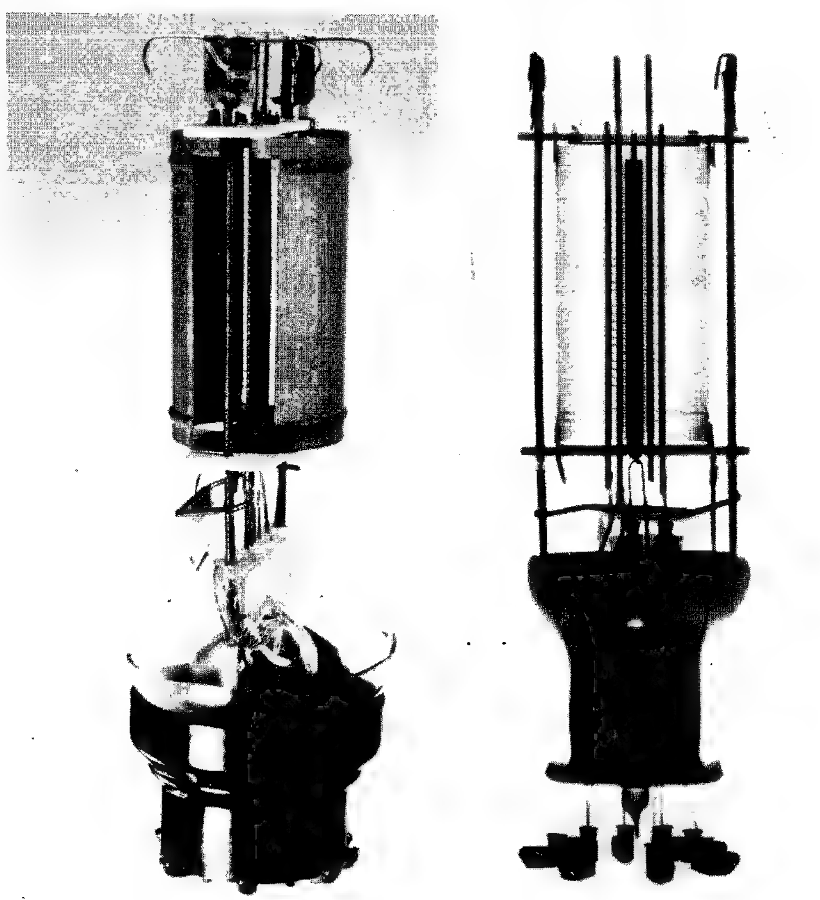


FOREIGN U.S.A.

V 6SK7 - FOREIGN AND U.S.A. X-RAYS



VI GENERAL CONSTRUCTION



Mount X-ray

VII - CERAMIC SPACERS IN THE FOREIGN AL4

mica is probably continuing at a high priority level. This sketch shows that the ceramic is indented at the cathode hole so that there is a minimum amount of thermal-conduction from the sleeve. One of the best ways in which the ceramic can be used is in conjunction with the German "pointed-end" cathode.

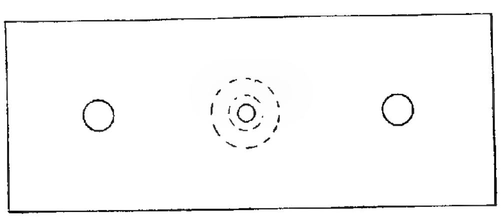
CATHODES

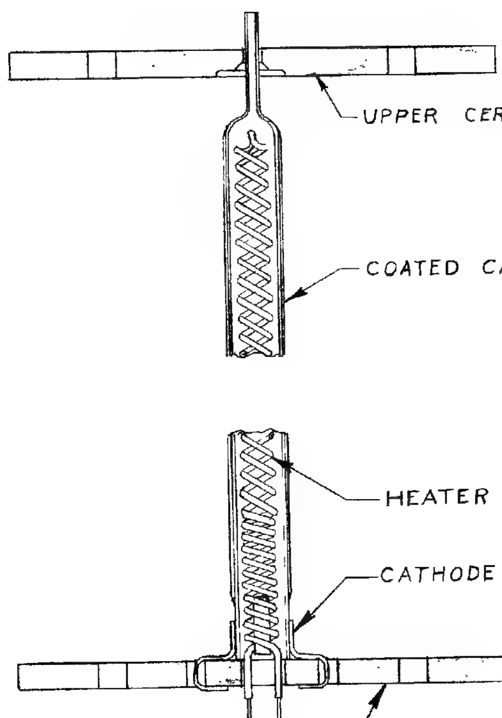
Slide No. 8 shows in an enlarged view of the pointed-end cathode which is obtained by swaging a conventional seamless round nickel sleeve. Also shown is the method for adapting to ceramic spacers. Automatic machines are available in Europe for swaging the cathode end. Frequently two additional lugs are welded or cut from the bottom of the cathode sleeve so that the tubing itself does not touch the bottom insulator. This still further reduces thermal-conduction heat loses.

ANODES

Slide No. 9 shows a photograph of a standard aluminized iron or P2 plate material in contrast with an equivalent plate of carbonized nickel as produced in this country. For many years even the advocates of the P2 plate material felt that close spaced rectifiers could not be made with this material. However, apparently means have now been found. As a result, aluminized iron is now the standard anode material in at least one tube plant or in one country which produces a fairly large quantity of good quality tubes. There is apparent agreement in both this country and abroad that a single steel works in the Ruhr supplies the best quality aluminized iron strip. Through standardization of the P2 anode stock, it has been possible for good processing controls to be placed upon the conversion process during exhaust, so that the degree of darkening is extremely uniform.

Figure 10 shows sketches of some recently standardized plate designs. They permit simple die and production equipment. Note that inspection slots have been





VIII. CERAMIC SPACERS

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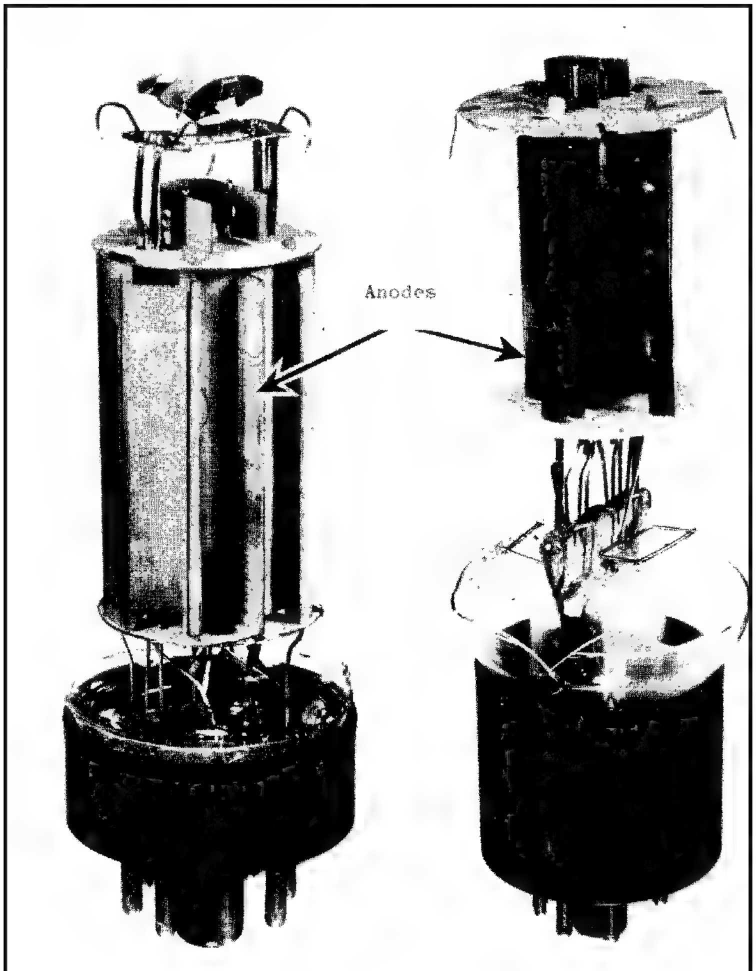
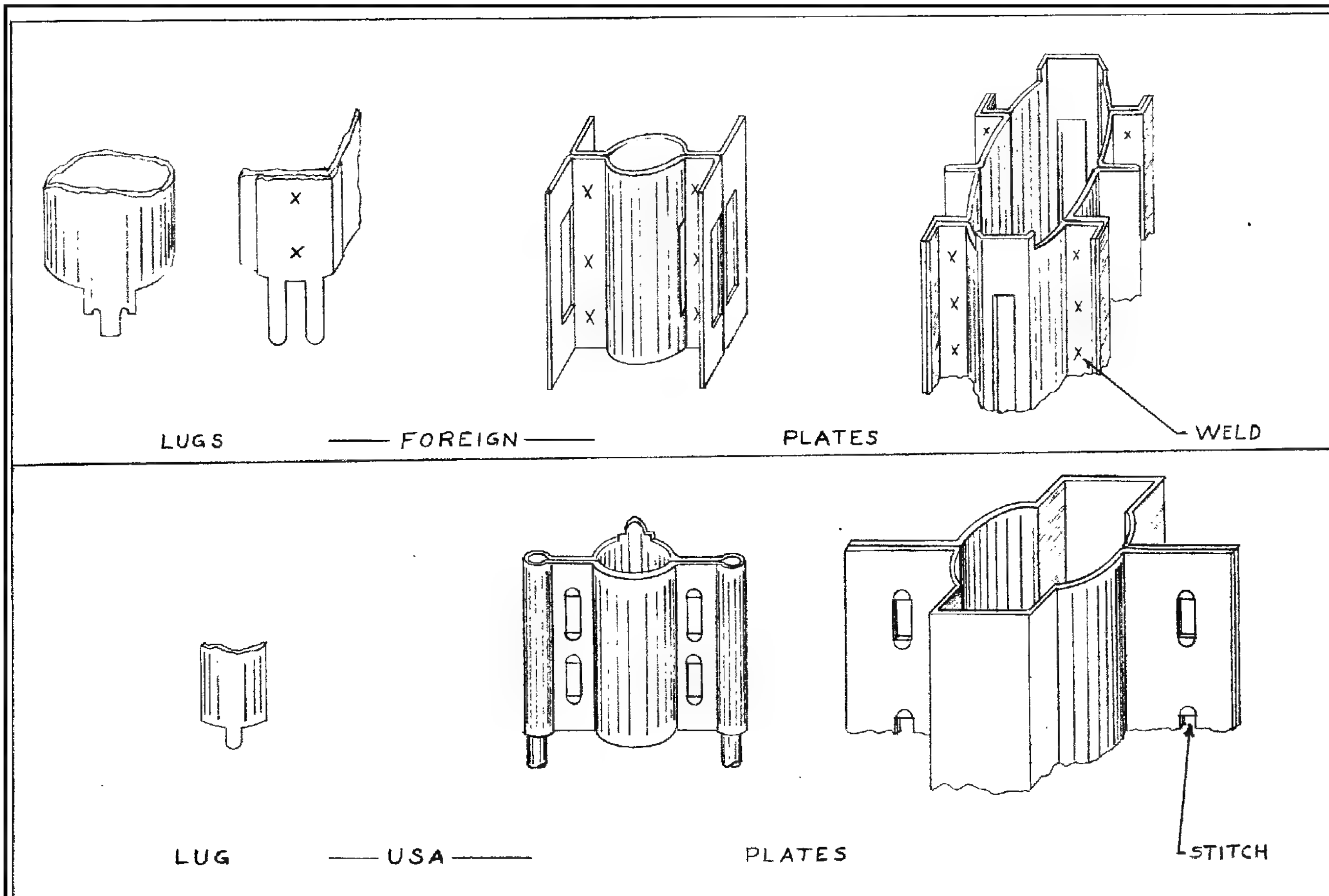


FOREIGN 6L6

U.S.A. 6L6

IX FOREIGN ALUMINIZED IRON ANODE AND U.S.A. CARBONIZED NICKEL



X LUG - PLATE DESIGN

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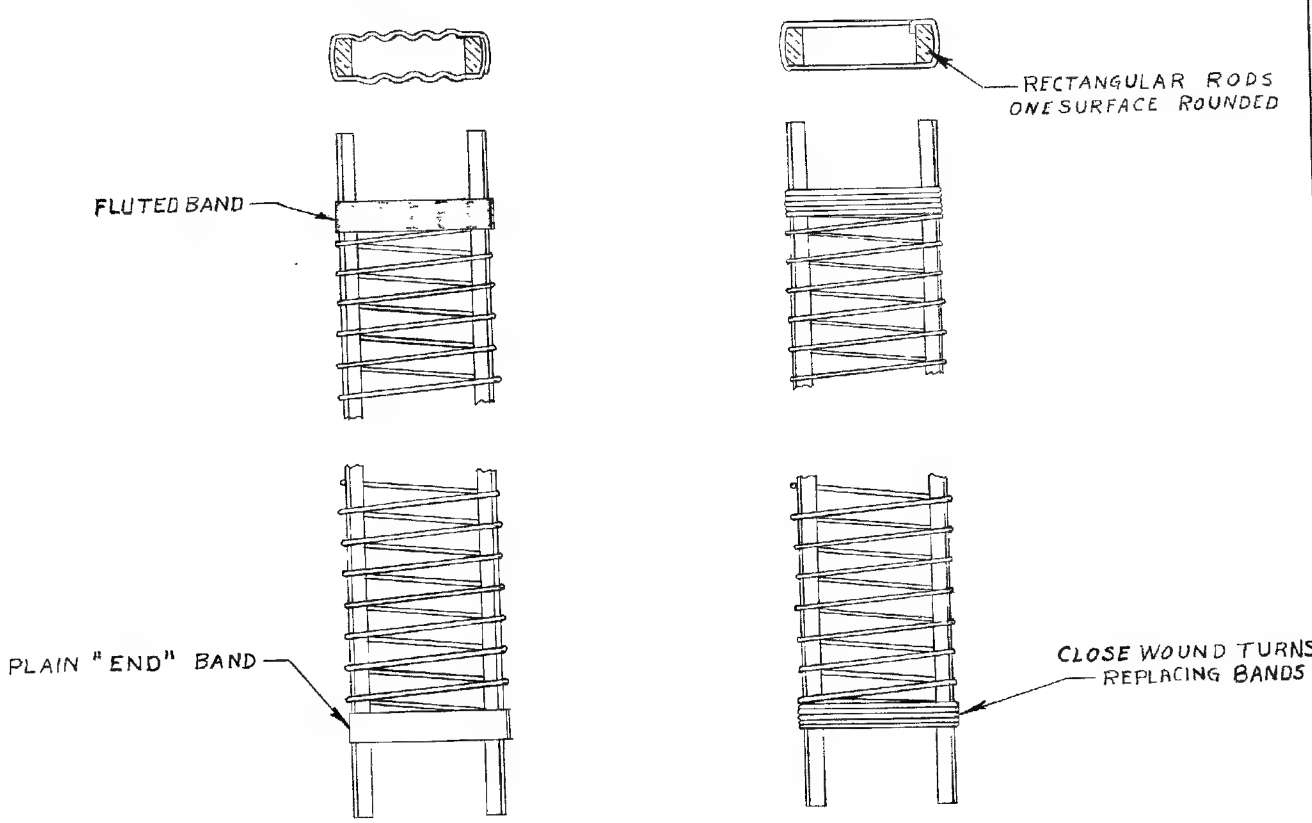
placed in both shields, plates, and beam confining plates so that operators may check their work with greater surety and adjustment may be made for alignment of the No. 1 and 2 grids during assembly. This slide also shows an improved plate lug design. This lug has an under-cutting adjacent to the shoulders. Thus the lug starts to twist below the mica. This insures a more secure lock since the edges of the lug bite into the mica and a larger degree of twisting above the mica is also possible. One feature which makes these lugs so effective is the very narrow slots available in the foreign micas. It is quite common in a mica as thick as .010 to .015" to have the width of the slots as small as .012". Two reasons may exist for these improved mica slots. First, a slower punching technique is probably used. Second, the mica which is available appears to be extremely well bonded. Our tests indicate that the mica is more closely laminated than the Brazilian material generally available in this country.

GRIDS

Slide No. 11 concerns grid structures. Welded grids are used abroad with great regularity. This requires that the wire and supporting rod materials have compatible welding characteristics. Nickel plated or clad copper rods are frequently used. We believe that this has an advantage since the nickel provides a stiffening sleeve which lends greater strength then for a wire of equivalent weight. The copper does not interfere with the welding, but does provide the greatest mass for maximum conductivity of heat away from the fine grid wire turns.

Rectangular grid side rods are sometimes used to advantage in producing grids with a narrow minor axis. Another technique is the use of a very fine pitch for the end grid turns. This is sometimes used in this country, but is much more prominent abroad. A band of nickel ribbon may also be welded around the ends of the grids to assist in retaining shape and improve the cut-off char-



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XI GRID STRUCTURE

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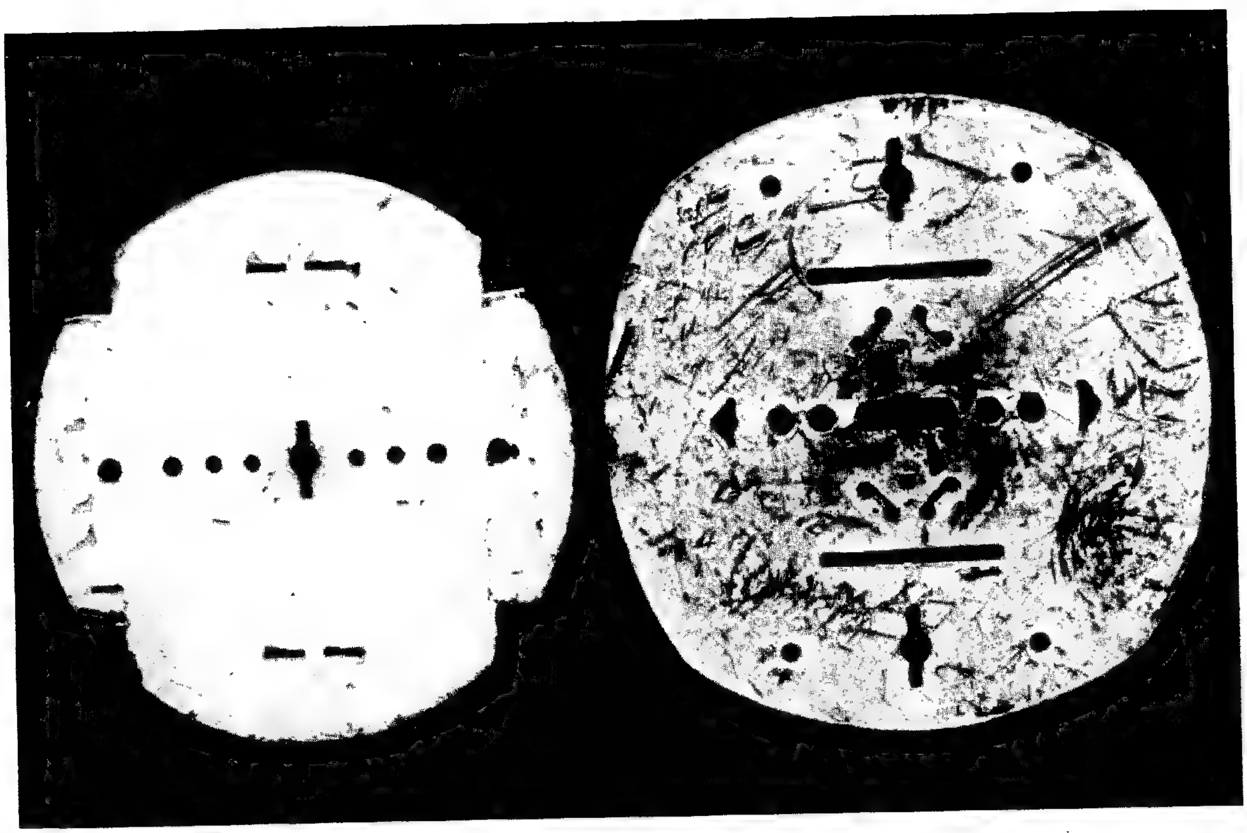
acteristics. Pushed end grid turns and consequent short circuits are thereby reduced considerably.

MICA SPRAY

Slide No. 12 indicates by photographic comparison the mica sprays used in one or more foreign countries in contrast with a conventional thin spray used here. Note that the foreign coating is extremely white, is free from discoloration around the cathode sleeve hole. Scratch tests show that it is extremely well adhered. We believe this is probably one of the most important developments which has been found in the analysis of foreign tubes. To the best of our knowledge the spray is the standard magnesia powder with a nitrocellulose binder added to it.

TUBE PROCESSING

After initial processing of tubes, it is normal to find not only conducting deposits upon the mica spray, but also barium oxide or barium films upon the grid wires and upon the insides of the plates and shields. These films have been studied, and the consensus is that they are broken down under electron bombardment and can then become dangerous to cathode life. From experience on the ASTM standard diode on laboratory exhaust systems, we know that it is extremely difficult to reduce this original film deposit. However, analysis of the tubes from several foreign countries indicates that conventionally they do not have such films on micas, grids, or plate surfaces. We do not believe that their exhaust procedures are any better than ours or that their pumps produce a better vacuum. Our information on this type of cathode coating indicates that it is very similar to our own and certainly the materials used in the electrodes of the tubes are not dissimilar from our own. We cannot suggest means for reducing or eliminating this coating which is known to be harmful, but we can suggest that it is possible and that indeed it has been possible to eliminate such films from production tubes. This



NORMAL FOREIGN
HEAVY SPRAYED MICA

NORMAL U.S.A.
TUMBLE-SPRAYED MICA

XII FOREIGN AND U.S.A. MICA COATING

is a challenge I fear and not a very great assistance to you at present. When a solution is found, then tubes should have greater electrical reliability.

ELECTRODE SPACINGS

One of the larger tube plants abroad has taken great pains to bring out the equivalents of the standard American GT types of radio tubes, meeting American electrical specifications.

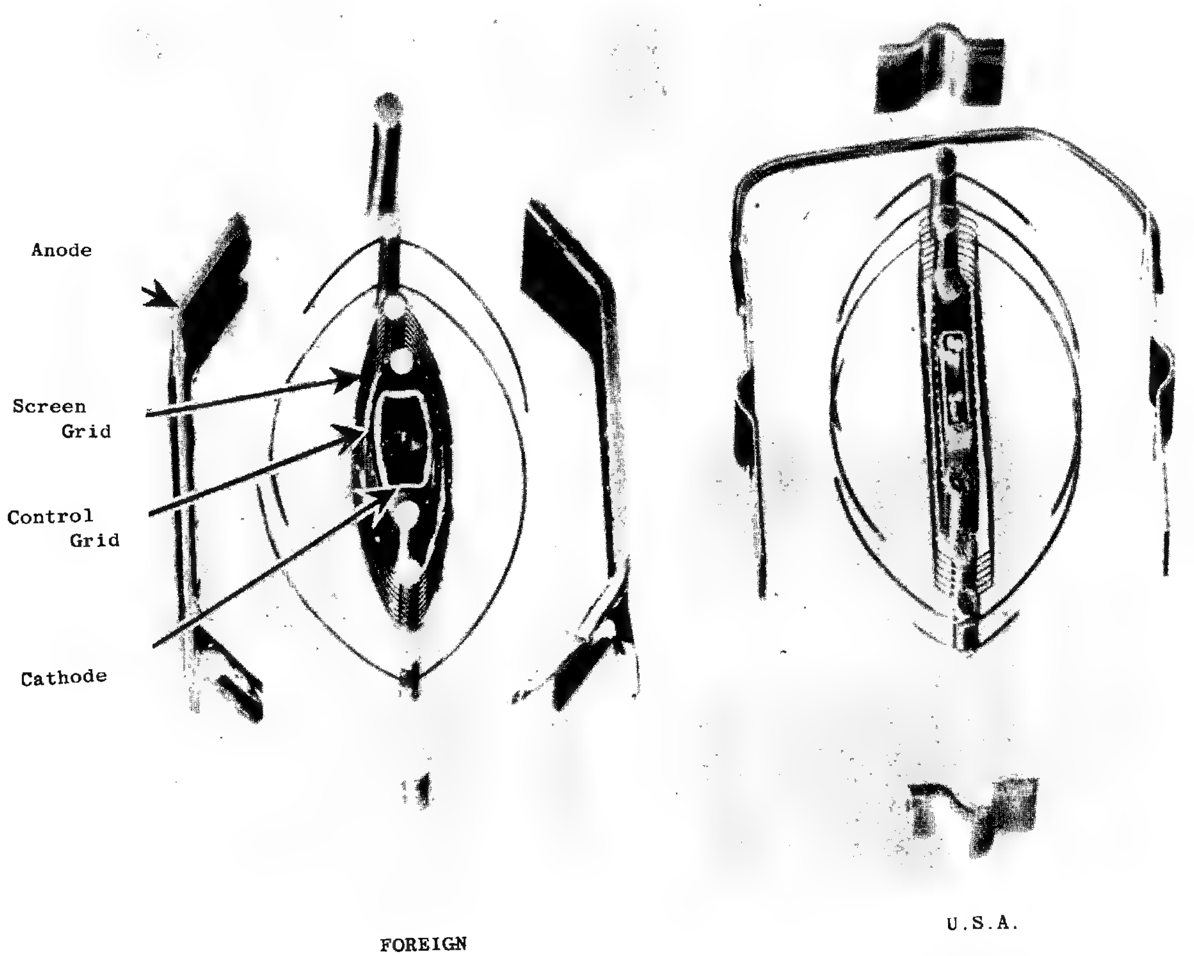
Slide No. 13 shows plastic cross section views of a foreign and U.S. type 6AG7 tube. The foreign cathode cross section has greater strength against bowing. The grid shape is more rugged and is such that expansion due to heating will increase grid-cathode spacing. These design parameters have permitted use of closer grid-cathode spacing in the foreign samples than in the U.S. samples.

However, dimensions and spacings on a large number of tubes, produced over a period of several years, indicates a specific trend to larger grid-cathode spacings in foreign tubes than in U.S. tubes.

Slide No. 14 presents in tabular fashion data on cathode, control, and screen grid dimensions of a series of tubes from several plants. Note that in the cathode to control grid spacings, it has frequently been possible for the foreign designs to achieve 10 to 100% larger spacing and yet maintain the same electrical characteristics. This, we maintain, is a major contribution to improved tube reliability.

Slide No. 15 is a graph of U.S.A. versus foreign cathode to control grid spacings for a variety of tubes. Should these spacings have been the same, all the points would have lain along the 45 degree line. The tendency for the points to lie above the line is graphical evidence that a general policy seems to exist of having the largest possible cathode to G1 spacings.

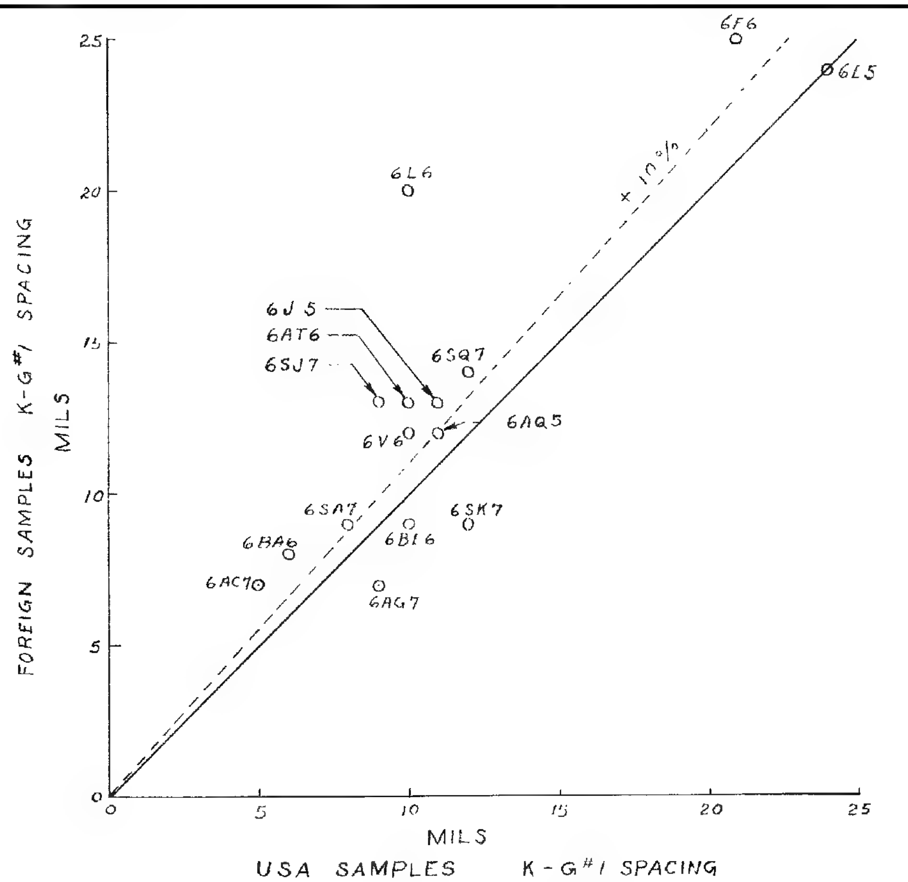
We would cite the use of thorium getters, both as paste on the screen grid which are flashed during aging as well as pellets in the retainers which are



XIII 6AG7 - FOREIGN AND U.S.A. CROSS-SECTIONS

XIV. COMPARISON OF FOREIGN TO DOMESTIC GRID - CATHODE DIMENSIONS

Tube Type (Foreign)	Cathode O.D. %	Cathode to Grid #1 Spacing %	Grid #1 Pitch %	Mesh Wire Diameter %	Side Rod Diameter %	Cathode to Grid #2 Spacing %
Triodes 6AT6	0	+30	+23	-25	0	—
6SQ7	0	+16	+7	-18	0	—
Pentodes 6AC7	+200	+40	+6	-25	0	+33
6BA6	0	+33	+13	-21	0	-7
6SJ7	0	+44	+7	0	0	-14
Power Output Types 6AQ5	0	+9	0	+30	0	0
6L6	+150	+100	0	+6	+57	-10



XV USA VS FOREIGN K-G#1 SPACING FOR SEVERAL TUBE TYPES

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flashed during exhaust. We could cite the extensive use of cataphoretic coatings, both to conserve materials as well as to obtain uniform deposits on heaters, cathodes, grids, and plates. The latter, of course, for transmitting tubes.

POWER OUTPUT PENTODE

Slide No. 16 concerns a power output pentode designated originally by Telefunken as the LS50. This tube fills the gap in power output between the 6L6, rated at 20 watts, and the small 100 watt transmitting tubes. The photographic view well illustrates the Telefunken wartime structure. It is compact, sturdy and the metallic end cap helps to provide heat dissipation. The x-ray view shows that the mount is closely attached to the strong button type stem leads.

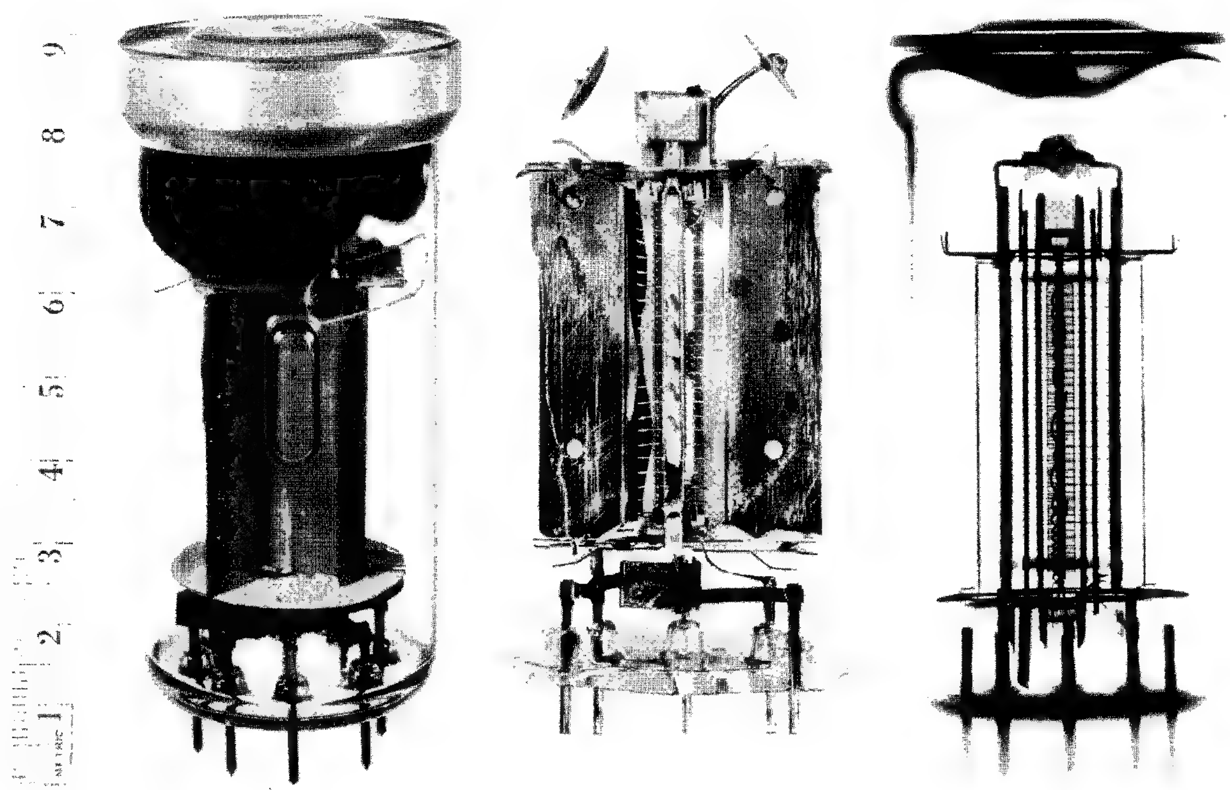
Slide No. 17 provides tabular information on the electrical ratings of the 6L6 and the related 5881 and 807 American tubes in contrast to an improved version of the Telefunken LS50 tube which is still in popular and growing demand abroad.

MULTI-SECTION TUBES

Figure 18 sketches an unique mica design applicable for triode, double diode tubes, such as the 6Q7. Conventionally in the US, the bottom triode mica has an enlarged cathode hole which permits the coated portions of the sleeve to pass through without damage. Then, to secure the cathode in axial alignment, three vertical embosses are formed near the mid-point of the lock-seam cathode. These embosses are difficult to produce and maintain within narrow control limits.

Foreign tubes, normally employing seamless cathodes, cannot employ vertical embosses. Often the cathode hole has had three mica figures extending inwardly which position the sleeve but scratch the cathode coating for the diode section.

A recent innovation has been seen, as sketched in fig. 18 c. The bottom triode mica has a sturdy flap created by an elongated, tear-shaped grid hole, and a lanced slot penetrating from the plate lug and peripheral indent. When



COMPLETE TUBE CROSS SECTION X-RAY

XVI LS50 - IMPROVED FOREIGN POWER OUTPUT TUBE

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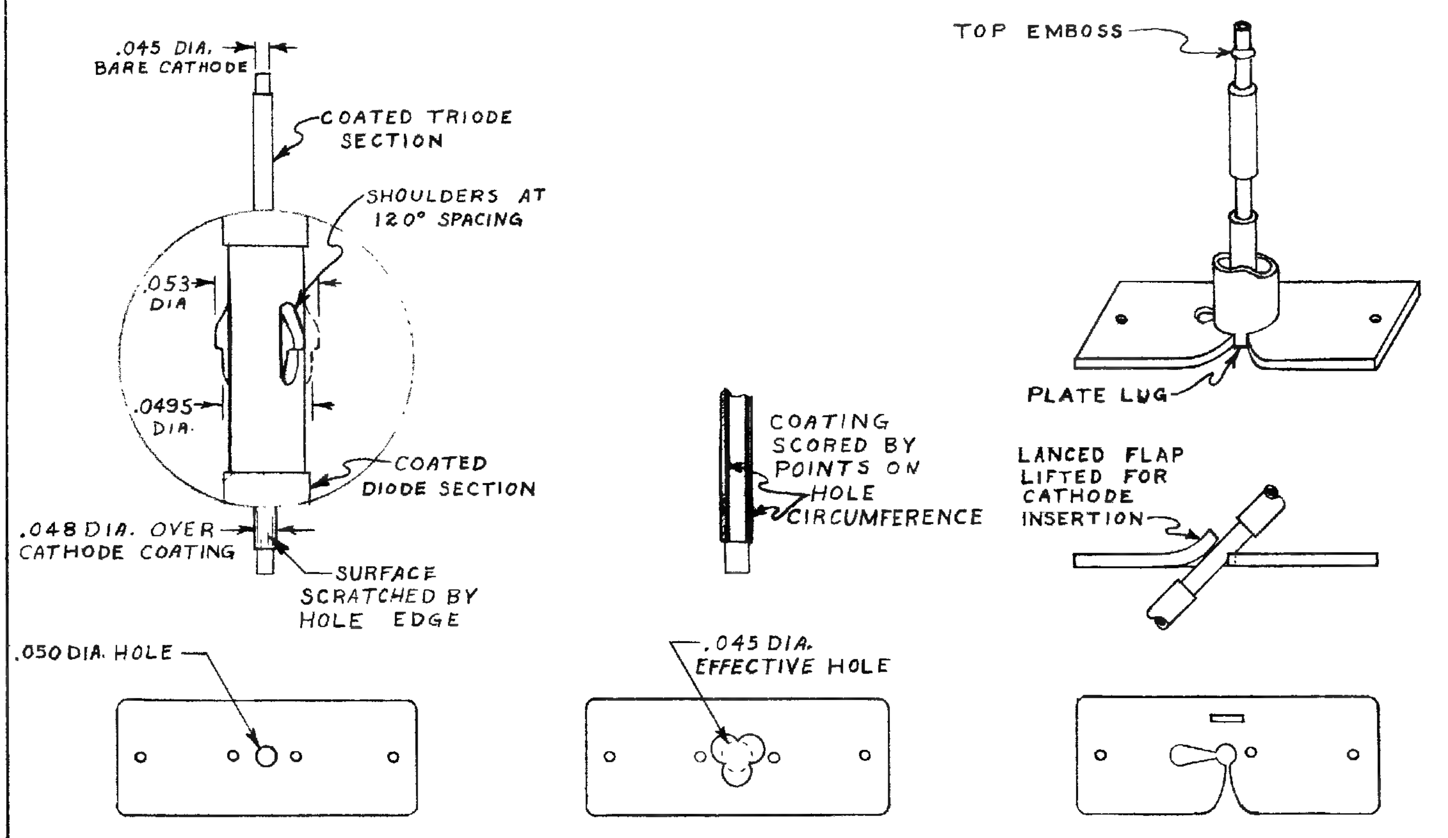
XVII. POWER OUTPUT PENTODE ELECTRICAL CHARACTERISTICS

Tube Type	E_f Volts ac	I_f Amp ac	*E_{c1} Volts dc	**E_{c2} Volts dc	**I_{c2} ma dc	**P_{G2} Watts	**E_b Volts dc	**I_b ma dc	**P_p Watts
USA 6L6	6.3	0.900	-30.0	270	7.0	2.5	360	80.0	20
USA 5881	6.3	0.900	-35.0	400	8.0	3.0	400	80.0	25
USA 807	6.3	0.900	-45.0	300	10.0	3.0	750	125.0	30
Foreign LS50	12.6	0.700	-120.0	300	20.0	5.0	1000	130.0	80

* Class "C" Operation

~~** Maximum Rated Conditions~~



18a. CONVENTIONAL U.S. CATHODE AND BOTTOM TRIODE MICA.

18b. POOR COMPROMISE DESIGN FOR PLAIN SEAMLESS CATHODE.

18c. RECENT FOREIGN DESIGN FOR EASY INSERTION OF PLAIN COATED CATHODE INTO BOTTOM TRIODE MICA.

FIGURE 18. CATHODE-MICA INSERTION

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the flap is slightly raised, as drawn in 18 c, the uncoated and unembossed central section of the cathode may readily be slipped into the cathode hole by tilting at an angle. With the flap released and the cathode vertical to the mica, there is a firm contact, and the sleeve is centered with respect to the grid and plate which have been added later. The flap is retained in the plane of the mica by bending an ear from the plate barrel under the mica.

This structure appears to be rapid for assembly, accurate for centering, and avoids difficult cathode production and control problems.

FILAMENTARY MINIATURE TUBES

When miniature tubes with fine filaments such as 1T4, 3S4, are assembled, there is difficulty threading the bottom connector through the grid structure and welding it accurately to the stem lead. Further, there may be relative motion between mount cage and stem, caused either during bulb sealing, or during shock and vibration. In either case the filament locationing and tensioning can be deteriorated.

A group of foreign filamentary miniature tubes has been seen recently wherein the filament is mounted as an integral part of the cage assembly. This is shown in fig. 19.

The structure employs a U-shaped stamping which locks tightly into the bottom mica by four lugs. These fold over flush with the top of this mica.

After the cage is completely assembled the filament is threaded through the mica triangular holes and the control grid. The top anchor coiled spring is welded to the proper support, such as the #3 grid rod. It is positioned by bending the flattened attachment tubing so that the filament top tab is about 1-2 mm above its final desired position.

A three gram weight is attached to the bottom filament connector. This hangs fire and thereby provides a uniform and controlled tension to the top anchor and filament. The bottom filament tab is welded to the bottom anchor stamping. Thus the 3 gram spring tensioning is retained. Excess length of

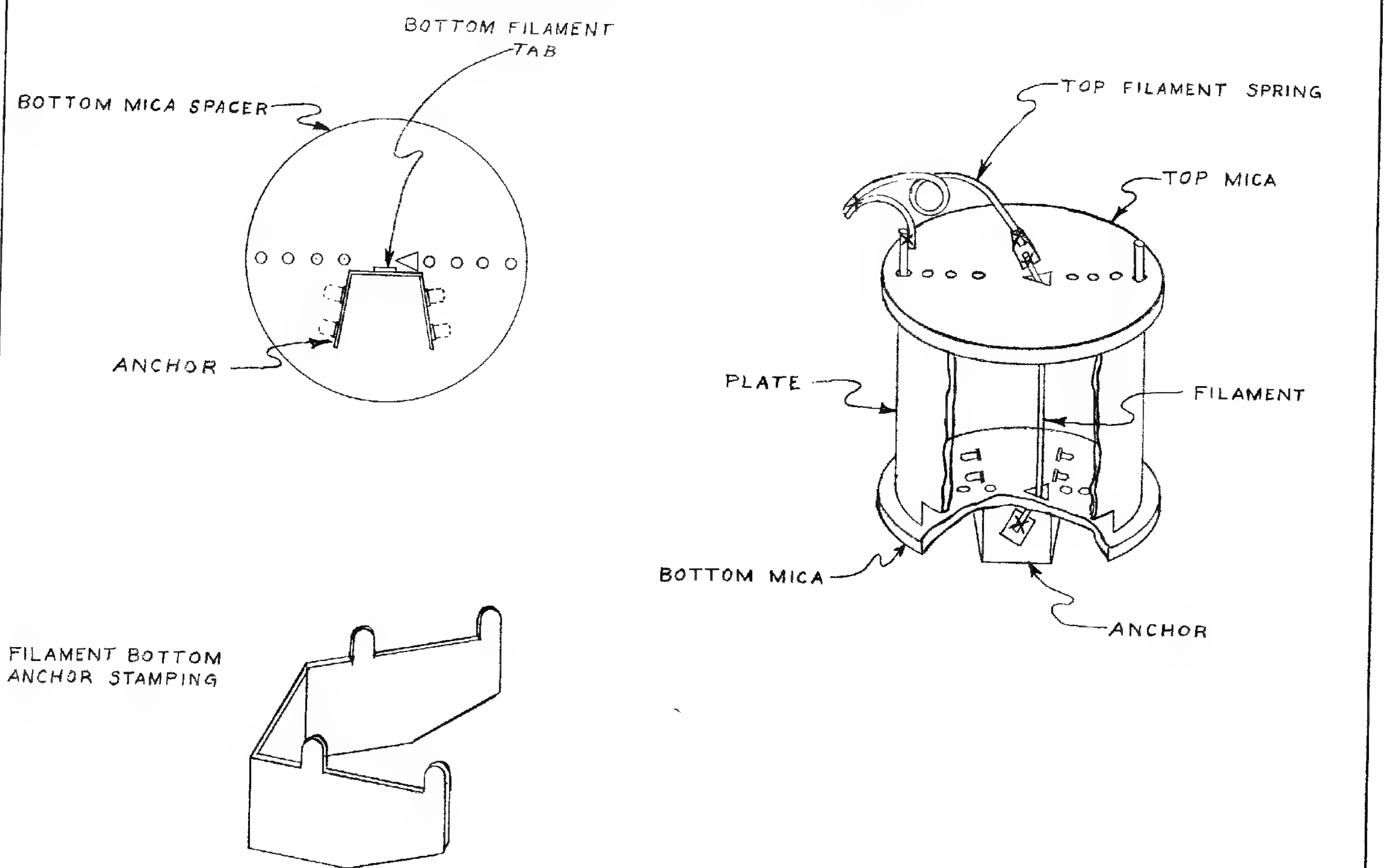

FIGURE 19 - UNITIZED FILAMENTARY CAGE STRUCTURE

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the tab is cut off. Final adjustments of all cage parts and filament positioning is then readily accomplished with the cage unencumbered by the button stem.

The last operation is to weld the inner stem leads to appropriate electrode wires. Deformation of the filament location should be relatively impossible.

Obviously similar designs might be incorporated into other filamentary tubes, or into cathode types having close working spaces, or rigorous requirements for heater location.

GENERAL

Metallized sprays on the glass bulbs are common in European tubes. Where heat radiation is required, a carbon under-coat precedes the aluminum paint spray. On top of the aluminum, a lacquer is normally applied. The adherence of these coatings is tenacious. The electrical resistance is of the order of a few ohms, when application is done properly. Grounding contacts are obtained by wrapping a copper wire around the top of a base shell and soldering it electrically into the cathode base pin. The conducting metallized sprays embed the copper close to the bulb. The formulae for the foreign coatings of high adherence quality are available from our files.

CONCLUSIONS

Our colleagues in foreign tube plants exhibit a large degree of engineering skill. Remembering that they are faced with economic conditions far inferior to our own, recognizing that their material situation is far from satisfactory and believing that their equipment requires excessive inexpensive manual labor, we are forced to admit that they have produced exceedingly well. It is quite probable that the overall quality of our domestic tubes exceeds that of the foreign tubes; however, we do suggest that some good features exist in these foreign tubes which might be incorporated to the further advantage of our own tubes, particularly those produced in small quantities and requiring the maximum of electrical and mechanical reliability.

THREE DIMENSIONAL TUBE DATA PRESENTATION

F. R. MICHAEL

Research Center
Burroughs Corporation
Philadelphia

"Three-dimensional" views of tube structures embedded in plastic have been made possible by techniques recently developed at the Philadelphia Research Center of Burroughs Corporation (formerly Burroughs Adding Machine Company).

The total effect of several drawings and cross sections is achieved in a single method of presentation that has proved most satisfactory where close-spaced, complex structures are involved.

Cross-sectional wedges of tubes embedded in plastic are cut at angles to the tube axis that are determined by the structural characteristics involved and the photographic effects to be achieved. These wedges are a distinct analysis and evaluation of the tube in one method of sample preparation.

The first cross sections made at Burroughs were cut perpendicular to the axis of the tube. Difficulties in photographic lighting were encountered which severely limited the value of the sample. Both thick and thin sections were cut (Fig. I). Sections that were thick enough to give a sense of tube depth were too difficult to illuminate internally. Thin sections were no better than a mechanical drawing.

A wedge-shaped section was next tried (Fig. II) in which

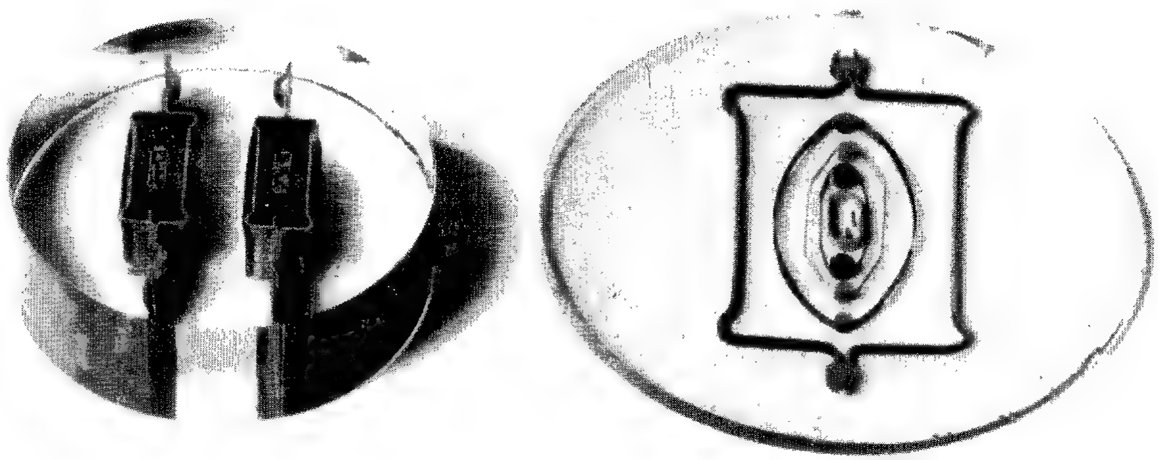


FIGURE I

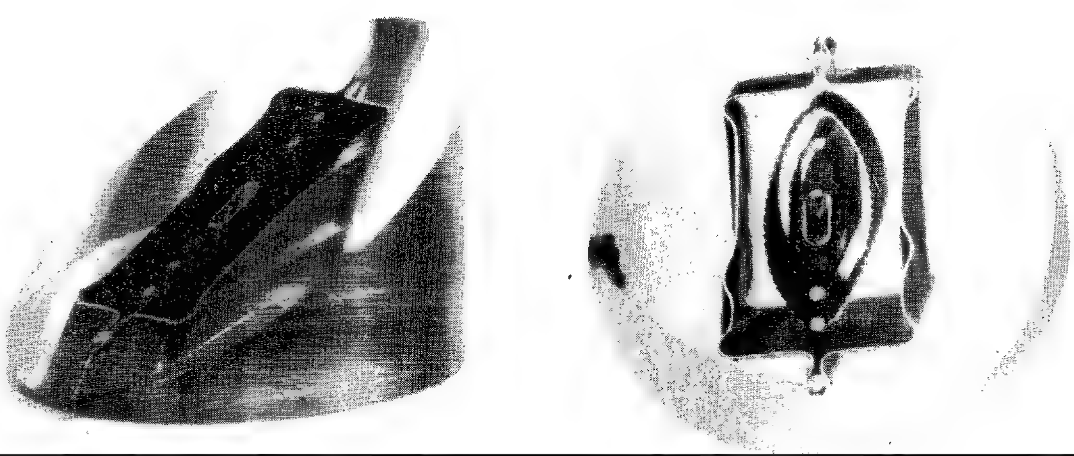


FIGURE II

one surface was cut at an angle of 45 degrees to the tube axis, and the other surface was cut at 90 degrees to the tube axis. Certain advantages were immediately noted: internal lighting was improved, and the intersections of grid mesh wires with the 45 degree plane gave a dotted, elongated contour of each grid that was fully photogenic. The possibility of taking dimensions that could now be measured on the surface of the plastic section was enhanced. By using an Epoxy type resin, such as Minnesota Mining and Engineering Casting Resin #2, shrinkage is held to less than 1%; with reasonable care in encapsulating, cutting and polishing, accuracy well within tube tolerances can be obtained. These Epoxy resins are amber colored, however; for photographic purposes, the clear Polyester type resin is preferred. This resin, such as Castolite, shrinks as much as 20% of its volume, and so cannot be used for reliable measurements.

Measurements taken from properly prepared samples can easily be converted to significant design ratios to be used as a basis for comparison between tube types, or the same type from different manufacturers. It is expected that the number of samples examined for a single comparison will properly reflect the significance to be attached to the results. The number of samples required may be reduced by selecting tubes by their electrical characteristics.

Internal illumination of the tube elements in the thicker part of the wedge was still unsatisfactory. It was then determined to cut the bottom plane B of the wedge at an angle to the tube axis as well as the top plane A. Some weird results were obtained. If the bottom plane is too steep, the grid turns are cut both before and behind, leaving unattached

grid wires suspended in the plastic and presenting a very odd impression of an electron tube. A method of determining α — the angle at which plane A is to be cut — and β — the angle at which plane B is to be cut — was needed. The following formula is based on assumptions found to be essential for best results.

In Figure III:

$$\tan\alpha = (h_1 + h_2)/W_1$$

and

$$\tan\beta = (H_2/(W_1 + W_2)$$

Experience gained from many trials indicated that

$$H_2 \cong (h_1 + h_2)$$

Assuming equality,

$$W_1 \tan\alpha = (W_1 + W_2) \tan\beta$$

or

$$\tan\beta = W_1 \tan\alpha /(W_1 + W_2)$$

Also

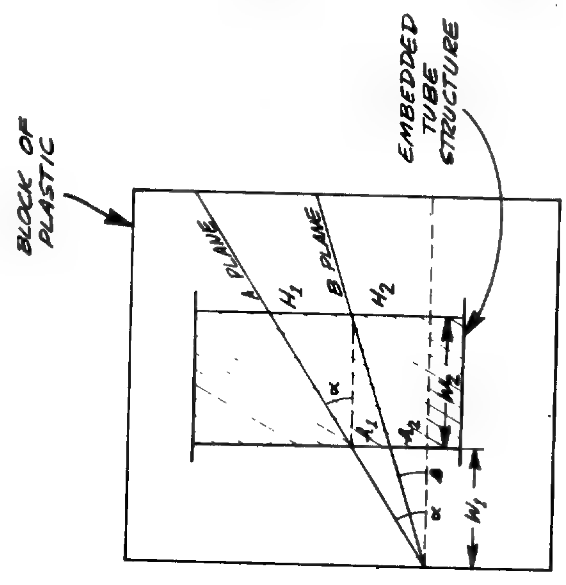
$$H_1 = N/T = W_2 \tan\alpha$$

giving

$$\tan\alpha = N/TW_2$$

In multi-grid tubes, N and T must apply to the same grid. For wide-pitched grids, N 5 turns; and for close pitched grids, N 25 turns seemed best.

In Figure IV the layout for photographing the wedge is shown. Note that reflected light is necessary to bring out the tiny grid wire



FOR $H_2 = h_1 + h_2$:

$$\tan\alpha = \frac{N}{TW_2}$$

$$\tan\beta = \frac{W_1}{W_1 + W_2}\tan\alpha$$

WHERE N = Number of grid turns intersecting plane A. Suggest $5 < N < 25$.

AND T = Number of grid turns per unit length.

FIG. III. DETERMINATION OF WEDGE ANGLES.

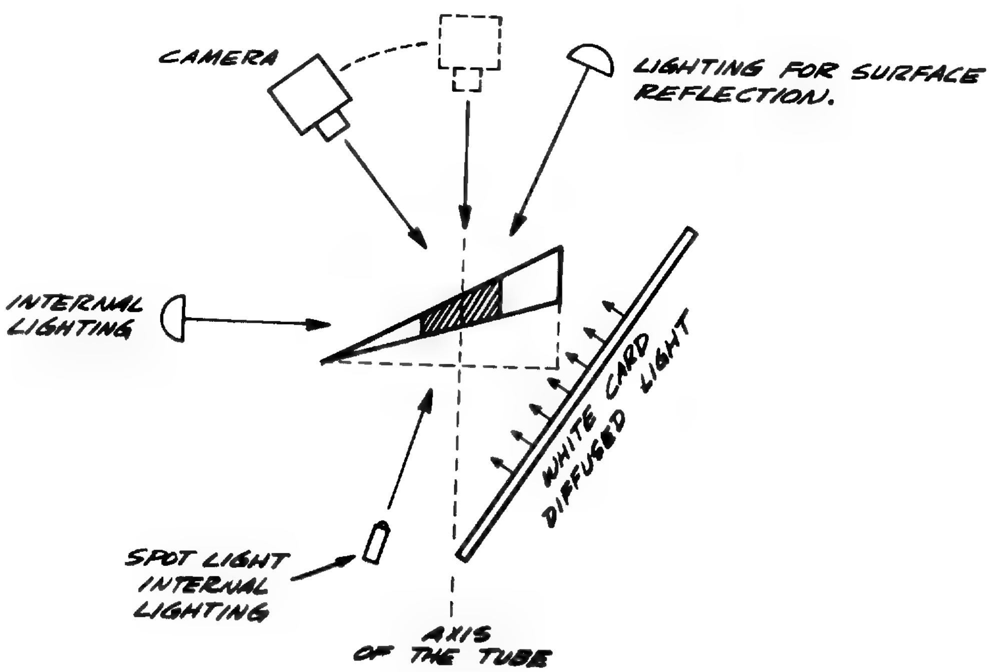


FIG. IV. PHOTOGRAPHIC LAYOUT.

intersections at the surface of the plastic. The angular-cut planes allow the illumination of the internal tube elements in a stepped fashion so that the anode, for instance, does not throw a shadow over the rest of the internal structure.

The obtuse wedge, properly cut, offers three definite advantages over the usual cross sections cut perpendicular to the tube axis:

1. Design ratios are easily measured on the surface of the plastic, giving concrete bases for comparison (Fig. V). These ratios could be:

   a. G_1 to G_2 pitch.

   b. Grid pitch to grid spacing from the cathode.

   c. Grid wire diameter to pitch or spacing (Fig. VI).

   d. Grid wire diameter to minor axial length.

   e. Spacings of the various electrodes.

2. Deformation and misalignment of the tube elements and their effects on tube operation are more easily seen. Note the heater position in the cathode sleeve of Fig. VI. Fig. VII shows the 7AK7 screen grid side rods pushed off center. The grid turns in this tube are intentionally well aligned to hold down screen dissipation. The intersections of the grid turns in the plastic show both this alignment and the G_1 to G_2 spacing effect of the pushed side rods.

3. An improved concept of the tube structure is obtained through better illumination of internal tube elements, giving a sense of depth to photographs. Examination of the sample is enhanced since the tube structure can be seen in greater detail. (Fig. VIII).

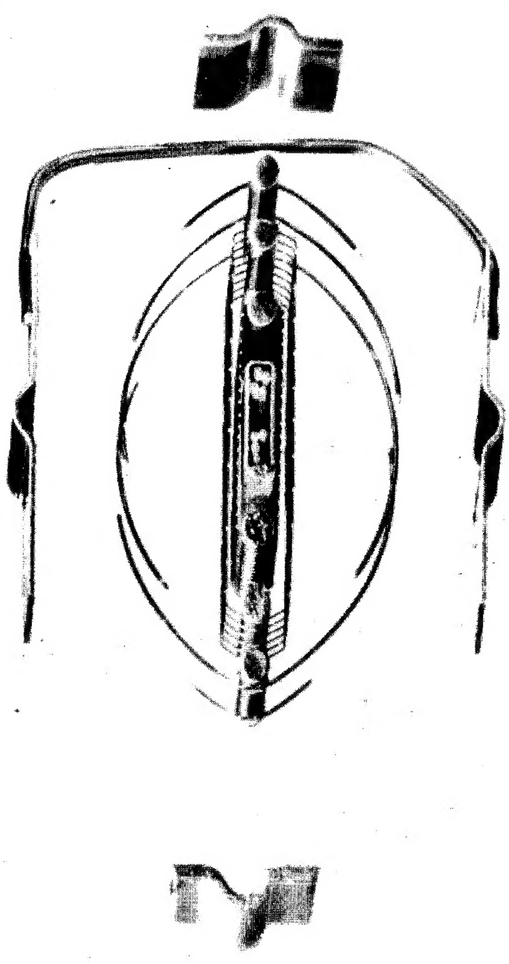


FIGURE V

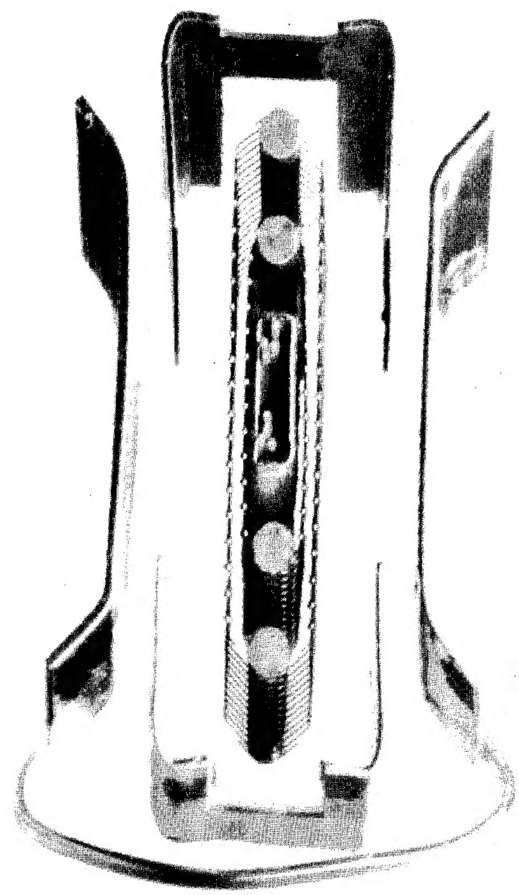


FIGURE VI

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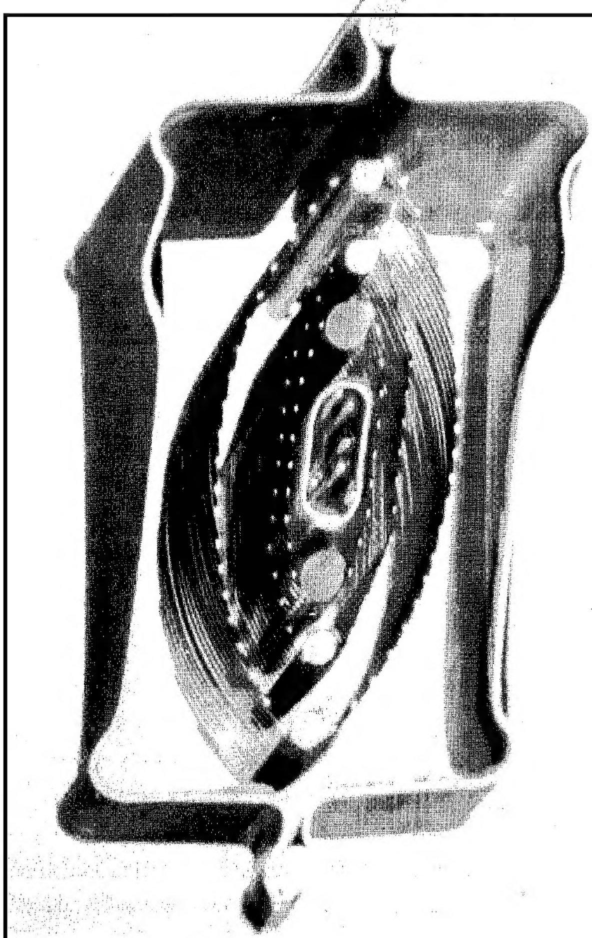

FIGURE VII

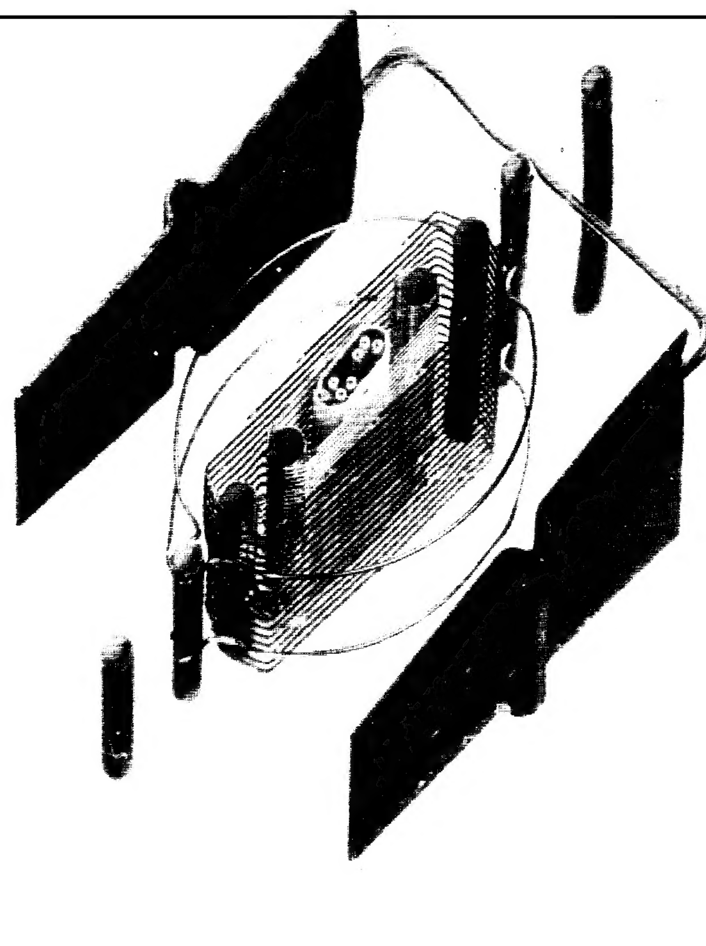

FIGURE VIII

Appreciation is extended to Mr. Frank Virgadamo of Burroughs Research, Philadelphia, for his assistance; Mr. George Bastier of Broadaxe, Pa., for his efforts in the photographing of these wedges; and to Mr. George Irvin of Philadelphia, for the plastic encapsulations.

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